Final Report for Period: 07/2010 - 06/2011
Submitted on: 06/28/2011
Principal Investigator: Cook, William J.
Award ID: 0726370
Organization: Georgia Tech Research Corp
Submitted By:
Cook, William - Principal Investigator
Title:
An Exact Rational Solver for Mixed Integer Programming

Project Participants

Senior Personnel

Name: Cook, William
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Name: Fukasawa, Ricardo
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate research assistant in Fall 2007 (1/6 time), Summer 2008 (1/2 time until July 31)

Name: Steffy, Dan
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate research assistant Fall 2007 (1/3 time), Summer 2008 (1/2 time), Fall 2008 (1/2 time), Spring 2009 (1/2 time), Summer 2009 (1/2 time), Fall 2009 (1/2 time), Spring 2010 (1/6 time), Summer 2010 (1/2 time)

Name: Chen, Kenneth
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate research assistant in Spring 2008 (1/3 time), Summer 2008 (1/3 time), Fall 2008 (1/3 time), Summer 2009 (1/3 time), Fall 2009 (1/3 time)

Name: Inkmann, Torsten
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate research assistant (1/3-time) in Fall 2008.

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Zuse Institue Berlin (ZIB)

Technical discussions on aspects of the project have taken place over the past two years. In Summer 2009, Daniel Steffy (PhD Student, GTech) spent 8 weeks at ZIB, collaborating on computational aspects of the project. In Spring 2010, Kati Wolter (PhD Student, ZIB) spent 8 weeks at Georgia Tech, continuing the computational work.

Other Collaborators or Contacts

Dr. Stephan Held from the University of Bonn, Germany, spent the academic year 2009/2010 at Georgia Tech as a Postdoctoral Fellow funded by the German Academic Exchange Service (DAAD). He worked full time on the NSF project, focusing on safe linear-programming methods for the solution of graph coloring problems.

Activities and Findings

Research and Education Activities:

We have carried out studies into the exact rational solution of linear and mixed-integer programming problems. The studies have focused on the solution of rational systems of equations, the production of provably accurate cutting planes, the development of accurate dual bounds for use in branch-and-bound methods for mixed-integer programming, and the handling of irrational objective functions.

Findings:

A major finding is the identification of a simple-to-use method for producing provably-accurate Gomory mixed-integer cutting planes and MIR cuts, using only floating-point software. This technique allows the
repeated use of these important classes of cuts within standard integer programming software. The method is currently being adopted for use in the CPLEX commercial system and other integer programming solvers.

A second major finding concerns the efficient solution of rational systems of equations. Our computational results on large-scale sparse systems indicate an order-of-magnitude speed-up over existing methods.

A third major finding is the creation of a hybrid symbolic-numeric process for computing safe bounds for mixed-integer programming models. This process has been incorporated into a branch-and-bound solver for the solution of general instances of mixed-integer programming problems.

Training and Development:

The project has provided the team of PhD students with skills in computational aspects of mixed-integer programming.

Outreach Activities:

I have continued to use my traveling salesman problem web site as a means to communicate new techniques in discrete optimization and mixed-integer programming. The number of page views is now over one million per year. I have also completed a popular account of the TSP to be published by Princeton University Press, with the title: In Pursuit of the Traveling Salesman: Mathematics at the Limits of Computation. The NSF project is cited in the book, and connections to the broad operations research community are discussed.

Journal Publications

Applegate, D., Cook, W., Dash, S., Espinoza, D., "Exact solutions to linear programming problems", Operations Research Letters, p. 693, vol. 35, (2007). Published, 10.1016/j.orl.2006.12.010.

Applegate, D., Bixby, R., Chvatal, V., Cook, W., Espinoza, D., Goycoolea, M., Helsgaun, K., "Certification of an optimal TSP tour through 85,900 cities", Operations Research Letters, p. 11, vol. 37, (2009). Published, 10.1016/j.orl.2008.09.006

Cook, W., Dash, S., Fukasawa, R., Goycoolea, M., "Numerically safe Gomory mixed-integer cuts", INFORMS Journal on Computing, p. , vol. 21, (2009). Published, 10.1287/ijoc.1090.0324

Cook, W., Steffy, D., "Solving very sparse rational systems of equations", ACM Transactions on Mathematical Software, p. , vol. 37, (2010). Published,

Dan Steffy, "Exact solutions to linear systems of equations using output sensitive lifting", ACM Communications in Computer Algebra, p. , vol. , (2010). Accepted,

Books or Other One-time Publications

William Cook, "In Pursuit of the Traveling Salesman: Mathematics at the Limits of Computation", (2012). Book, Accepted
Bibliography: Princeton University Press

Cook, W.; Koch, T.; Steffy, D. E.; Wolter, K., "An exact rational mixed-integer programming solver", (2011). Conference Proceedings, Published
Editor(s): Gunluk, O.; Woeginger, G. J.
Collection: Integer Programming and Combinatorial Optimization, IPCO 2011
Bibliography: Lecture Notes in Computer Science 6655, Springer, pages 104--116.

Held, S.; Sewell, E. C.; Cook, W., "Safe lower bounds for graph coloring", (2011). Conference Proceedings, Published
Editor(s): Gunluk, O.; Woeginger, G. J.
Collection: Integer Programming and Combinatorial Optimization, IPCO 2011
Bibliography: Lecture Notes in Computer Science 6655, Springer, pages 261--273.

Web/Internet Site

URL(s):
http://www.tsp.gatech.edu/
Description:
This TSP site is used to promote discrete optimization in the general public. The new material on the solution of the TSP instance pla85900 relates to the exact-rational solver in that provably accurate bounding techniques are used to verify the optimal solution.

Other Specific Products

Contributions

Contributions within Discipline:
The development of provably accurate Gomory mixed-integer cuts will be adopted in major mixed-integer programming codes. Our current work on the rational solution of large-scale sparse linear systems may have impact in a number of application areas.

Contributions to Other Disciplines:
The adoption of accurate Gomory mixed-integer cuts should improve the performance of widely adopted integer programming software, and this will in turn impact the many disciplines that make use of such computer codes. The efficient codes for the solution of rational systems of equations will likely find application in the linear algebra community.

Contributions to Human Resource Development:
I have written a general-interest book devoted to the history, application, and computation of solutions to the traveling salesman problem.

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Any Product
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering
Any Conference